THE WATER SUPPLY AT WILMINGTON, DELAWARE

By Edgar M. Hoopes, Jr. C.E.[1] and James M. Caird[2]

In Wilmington, as in many other cities of the country, the water supply was derived originally from a number of wells with wooden pumps, and although the city was founded in 1658 by a Swedish colony, it was not until a century later, namely 1796, that the first movement for concentrated action tending toward the establishment of a general system took place. The first resolution upon the subject of water supply was introduced in the borough council under date of December 31st of that year, and provided for a committee "to inquire of the inhabitants of the borough who owned pumps which stood in the street, whether they would be willing to give them to the corporation who would take care to have them kept in order."

This committee was continued from year to year and evidently fulfilled its mission, but four years later the growing importance of the borough demanded some better system and another committee submitted a report and an estimate for pumping the water from a spring on the hill at Third and Tatnall Streets, to Market Street.

The estimate of the above committee was as follows:

	£	s	d
835 feet of pump logs for mains, cost	57	8	½
Digging and hauling for mains, cost	7	1	10½
Cistern to contain thirty hhds	48	0	0
	112.	9	11

Owing probably to the extravagance of this estimate, the project failed to materialize, and no further progress was made until the year 1804 when the Wilmington Spring Water Company was incorporated.

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This Company had the power to levy a sum of money on such persons as should use water from their works. They remained in existence, extending their plant from time to time, until the year 1810, when it seemed to be the desire of the citizens that the stock of the said company should be owned by the Borough. The plant was therefore purchased for the sum of $10,000, and this date marks the inception of the Wilmington Water Department, ranking it as one of the earliest municipal water plants of the country.

The growing population evidently proved a tax upon the spring water supply and the pumps about the streets, and from time to time it was found necessary to increase these works until they could no longer accommodate the demands of the citizens. On June 5, 1820 action was taken relative to securing a water supply from the Brandywine Creek, and a committee appointed to report the probable cost of such a project.

This committee recommended a plant that could take water from the southerly side of the Brandywine, east of King Street, and that the water be forced through iron pipes to a reservoir located at the junction of Tenth and Shipley Streets, and thence be distributed through iron pipes to the city. The original site selected is the location of the present pumping station and plant.

Definite action upon this report was evidently not taken at the time it was submitted, for from the records it appears that the reservoir was not built and the existing works were enlarged by introducing new cisterns.

In June 1827, the first definite project for the introduction of Brandywine water into the city mains was inaugurated by the purchase of the water rights and mill property on the Brandywine, belonging to Mr. John Cummins, and the construction of a reservoir on the square bounded by Market, King, Tenth and Eleventh Streets, which is the present site of the county court house. This work was completed in the fall of the same year and the first water was raised by the double acting pump to the new reservoir at midnight on November 15. This pump was operated by water power, the water falling on an overshot wheel 14 feet 6 inches in diameter, carrying forty buckets, each bucket containing 2 cubic feet of water when full. It was manufactured by Prosper Martin of Philadelphia and was similar to those installed for the Philadelphia works at Fairmount Park Station.

Owing to the fact that there was a storm of opposition to the plan, the committee, while fully impressed with the conviction that the pump would eventually do as they had calculated was somewhat doubtful of the success of its first trial, and kept the event from the knowledge of the citizens. The result was that at the time of testing the pump, it was known only to thirty or forty persons, among whom were the most steadfast and zealous friends of the plan. The record also states "that many of these failed even to tell their better halfs, and as a consequence great uneasiness was manifested by some of them at the nonappearance of their missing husbands at a late hour, and the services of friends were engaged to look them up."

It is interesting to note that when the pump failed to turn over owing to the fact that the gate was but partly raised, the omnipresent "I told you so" proclaimed the project a failure, but when the full head of water had been turned on the ponderous wheel revolved, and the double action pump was set in motion.

From a historical standpoint the following quotation from *The American Watchman* of December 4, 1827, may be of some interest.

NEW WATER WORKS

According to promise we lay before our readers some further particulars respecting the works just completed for supplying the Borough with water. For most of the details, we are indebted to the politeness of Jonas P. Fairlamb, Esq., Civil Engineer, whose professional services were engaged by the Corporation for this important work and it affords us pleasure to state that the result of a trial of the machinery has proved the accuracy of his calculations and borne honorable testimony of his talents as an engineer.

The capacity of the original reservoir, as supplied by this pump, was 1,000,000 gallons, and was enlarged as the population of the borough increased until the demand for better pressure in the outlying districts necessitated the construction of a reservoir at a higher elevation. This demand was satisfied by the installation of the Rodney Street reservoir (now abandoned) in the year 1863. Later, 1873–77 the inadequate storage capacity of the low service reservoir was augmented by the construction of Cool Spring reservoir, this having a capacity of 40,000,000 gallons.

No further changes were made in the present system until recent years, and the department remained under the direct control of the borough and under the management of a water committee until 1833,

when the state legislature, at the request of a number of citizens, created the board of water commissioners to whom was entrusted the care and management of the water and the improvement of a water supply system.

THE EXISTING SYSTEM

The source of supply has not been changed, the water being diverted from the Brandywine Creek, at a dam approximately 4800 feet up the stream, from the main pumping station, to which it is conducted by a race on the south side of the Creek.

Originating in the lower counties of Pennsylvania, the Creek has a total length of approximately 35 miles, with a drainage area of 335 square miles above the city dam. Owing to the number of small towns and villages, together with various classes of manufacturing plants, located on the watershed, the water is contaminated to a marked degree. In recent years the Board of Water Commissioners of the City, assisted by the State and City Boards of Health, have endeavored to remove the principal sources of pollution, and, while this has been accomplished to a considerable extent, by a rigid enforcement of the laws, and regulations governing the pollution of the stream within our own State—it has been impossible to secure any satisfactory results in Pennsylvania, which controls two-thirds of the watershed, and where the gravest dangers from sewage pollution exists.

Table showing typhoid fever deaths and death rate before removal of some sources of pollution

YEAR	DEATHS	RATE
1900	36.0	47.0
1901	32.0	41.0
1902	42.0	52.0
1903	54.0	66.0
1904	43.0	51.0
Average five years.	41.4	51.4

The sanitary work on the watershed commenced in 1905 several sources of pollution being removed, following which there was a reduction in the typhoid fever death rate.

Table showing typhoid fever deaths and death rate after removal of some sources of pollution

YEAR	DEATHS	RATE
1905	32.0	38.0
1906	34.0	40.0
1907	30.0	35.0
Average three years.	32.0	37.6

These results show that following improvements on the watershed there was a reduction of 26.9 per cent in the typhoid fever death rate.

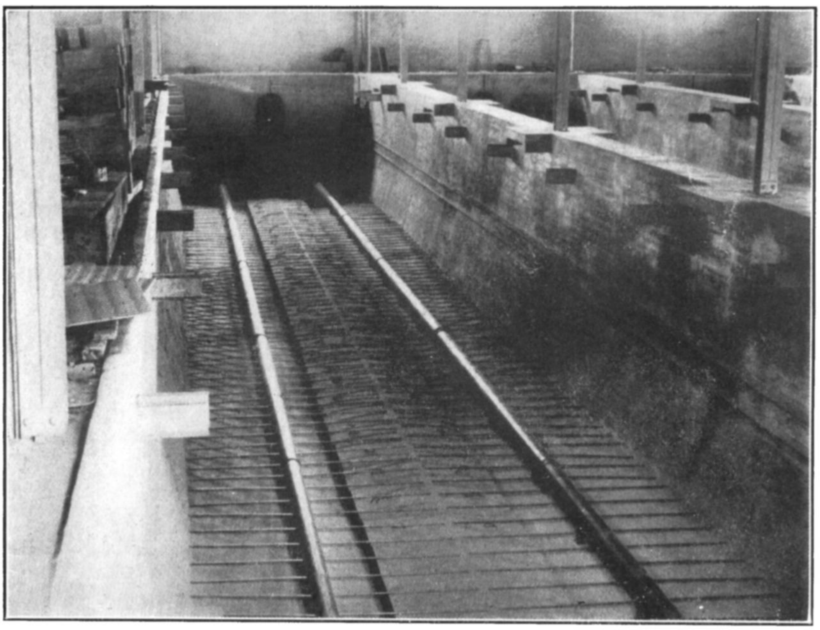
In the year 1892, the Board installed a purification plant known as the Sellars filter, and this, until early in 1903, had been supposed to be giving excellent service. Such however was not the case, as a thorough physical and bacteriological investigation clearly indicated.

A movement towards securing a more efficient system of supply, was therefore inaugurated early in the summer of 1902, but this was looked upon primarily as an extension to the then present system, and was brought about principally to relieve the precarious condition on the high service, or the Rodney reservoir.

The growth of the city has been such that the capacity and elevation of this reservoir were insufficient, and furthermore its length of service had rendered its condition not only treacherous but dangerous to public safety. A site was selected and purchased late in 1902 for the construction of a larger reservoir at a higher elevation, but legal obstacles delayed the beginning of the work until the fact that the old filter was of no benefit as a purifier was brought into the lime light, and the purification of the city's supply was agitated, discussed and finally decided upon. In the solution of this problem, the troubles of the department began. They were many and of a varied character, including the recommendation of new sites, suits in court, arbitration proceedings and principally financial embarrassment. One by one they were overcome, and by piecemeal the work has reached its present state. There have been to date ten major contracts awarded and completed which include the following: The supplying and laying of approximately 9000 linear feet of 43 inch lockbar, steel force main; 10,500 feet of 48 inch lockbar, steel distributing main; two 12,000,000 gallon Holly vertical, triple expansion pumping engines; four 300 h.p. Edge Moor water tube boilers and accessories; the construction of a large pumping station, boiler house;

35,000,000 gallon storage reservoir; a preliminary filter of 15,00,000 gallon daily capacity; a reinforced concrete seven arch bridge and aqueduct, 363 feet long; and the construction of a slow sand filter plant of the intermediate type, having a daily capacity of 15,000,000 gallons, including a 6,000,000 gallon filtered water reservoir.

The water passes through the diversion canal or race, to the preliminary filters, thence by gravity to the pumps and is raised by them to the new (Porter) reservoir. After approximately three days of



AIR WASH MANIFOLD OF ONE PRELIMINARY FILTER BED

sedimentation it flows by gravity on to the final filter beds, thence to the filtered water reservoir, and finally to the 48-inch steel distribution main supplying the high service system direct and the low service (Cool Spring) reservoir.

THE PRELIMINARY FILTERS

This plant consists of ten beds of 14 feet 5 inches by 100 feet and a reservoir 105 feet 9 inches by 30 feet 4 inches inside dimensions

with a depth in each of approximately $8\frac{1}{2}$ feet. The construction of the foundations and filter walls was of reinforced concrete, the superstructure being of brick, with limestone trimmings. After drawing the water from the race, it is fed to the beds from an influent gallery and, passing under the filter medium, through the inlet drains, is distributed by them over the area of the bed. The system of filtration is upward, the water rising from the drains through 6 inches of gravel of various sizes, thence through 20 inches of small coke, and finally through 20 inches of sponge clippings, the later being held in place by cypress racks. After passing the bed, the water is delivered into an effluent gallery and conveyed thereby to the clear well.

The distinguishing feature of this plant is the method employed in cleaning the filter medium. Unlike other plants of its type (in which the sponges are removed) the washing of the coke and sponges is done directly in the beds with air and water.

For this purpose, there is installed in the bed under the filter medium, a system or manifold of air pipes, consisting in each bed of two 6-inch main headers with $\frac{1}{2}$-inch laterals at 12-inch intervals. The latter pipes are plugged at the end and perforated with $\frac{1}{16}$-inch holes on 3-inch centers. The flow of air is secured from a rotary blower, and is discharged through the bed under about 5 pounds pressure. Water is discharged through the bed under normal operating heads in either direction, up or down, and the dirty or wash water is carried off by suitable connected drains. This system of cleaning the sponge clippings and coke has been found not only satisfactory, but very effective, and is carried on at a greatly reduced cost of operation and maintenance, only one attendant being required at all times.

The preliminary filters were placed in operation in October, 1907, two years before the final or slow sand filters.

Table showing average bacteria per cubic centimeter raw and pre-filtered waters, Wilmington, Delaware

YEAR	RAW	PRE-FILTERED	PERCENT REMOVED
1908	4306	2023	53.02
1909	2916	1448	50.35
Average two years....................	3611	1736	51 69

These filters are operated at the rate of about 50,000,000 gallons per acre per day.

Table showing average turbidity, in parts per million, raw and pre-filtered waters, Wilmington, Delaware

YEAR	RAW	PRE-FILTERED	PERCENT REMOVED
1908	26.0	9.0	63.08
1909	39.0	15.0	61.53
Average two years	32.5	12.0	62.35

The turbidity removal was slightly higher than the bacterial.

Table showing deaths from typhoid fever and death rate, two years operation of pre-filters, Wilmington, Delaware

YEAR	DEATHS	RATE
1908	21	24.0
1909	25	27.0
Average two years	23	25.5

Table showing average deaths from typhoid fever and rate, three years before and two years after filtration

	DEATHS	RATE
Before	32	37.6
After	23	25.5

These results show that after the prefilters were in operation the typhoid fever death rate decreased 32.2 per cent.

THE PUMPING STATION

The interior dimensions of this building are 60 by 110 feet by 54 feet the last dimension being the height for two floors. The interior basement walls are of Kittanning brick, while above the main floor the walls are of porcelain faced brick wainscoted with white enameled brick and a brown enameled brick baseboard. As noted before, there are installed two 12,000,000 gallon engines, and there is space available for the installation of a larger unit. The exterior walls of the station are of light buff, mottled brick, with granite and terracotta trimmings.

THE SEDIMENTATION RESERVOIR

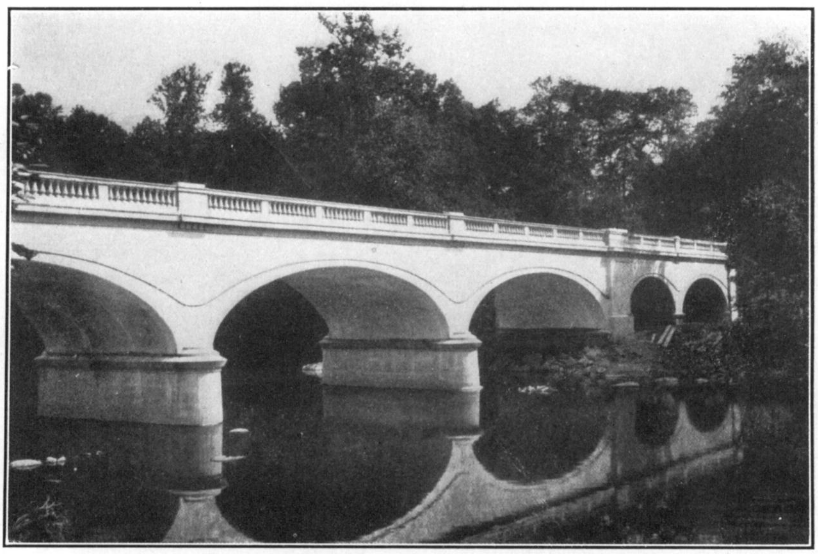
The total capacity of this reservoir is 35,000,000 gallons of which 32,000,000 are available. It is located on the 89 acre tract of land originally purchased by the Board for its construction and is distant from the pumping station about $1\frac{3}{4}$ miles. It is triangular in shape, with rounded corners, and is located with reserve space for a similar reservoir, when future extension is required. The maximum elevation of water is 285 feet above mean low tide, or city datum, and the

FILTERED WATER RESERVOIR (UNDER FILTRATION PLANT)

depth of water ranges from 21 feet over the sump to 17 feet at the inside toe of the embankment. The inner slope of this embankment is $1\frac{1}{2}$ to 1 and is paved with concrete and Belgian block upon a lining of 12 inches of clay puddle. The bottom is all concrete, laid on a bed of 12 inches of puddle. The exterior slopes are variable, reaching a maximum of 2 to 1. Around the top of the embankment there is an 8 foot macadam roadway, with a 2 foot cement walk and a Scotch coping rubble wall 3 feet high. The 43-inch forcing main discharges the water to the reservoir through four branches at a point 400 feet from the apex of the triangle. At the apex, the water is drawn off

over sluice gate weirs constructed in a tower and is thence delivered to the final filters. This tower is so constructed that its upper story serves as a pressure tank for local supply about the plant.

In the laying of the large mains numerous difficulties had to be overcome, many of which required change of alignment, after the pipe had been designed and purchased. While the majority of this pipe was of the lockbar type, there were occasional instances where short radius bends required the use of ordinary rivetted steel construction.



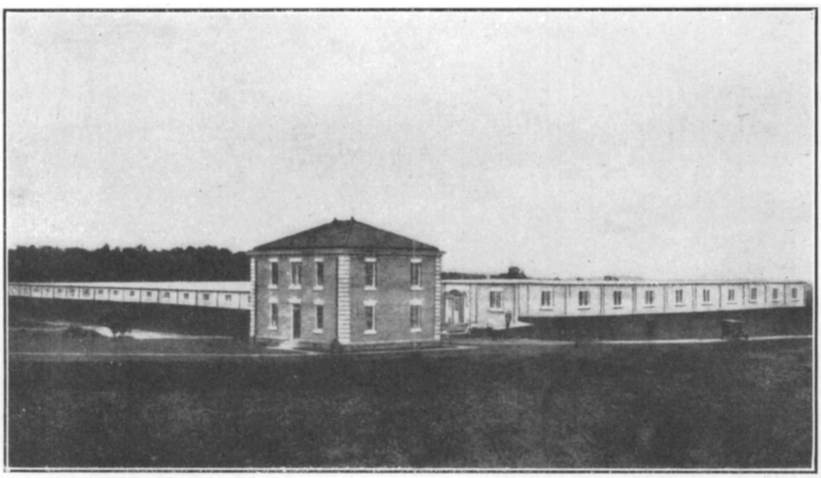
Van Buren Street Bridge and Aqueduct

VAN BUREN STREET BRIDGE

It was originally intended that the distribution main should be laid under the bed of the Brandywine Creek, at its crossing at Van Buren Street, but, after some discussion, it was decided to build a bridge for this purpose, and also to accommodate the traffic between the parks on each side of the stream. To this end the cost of the work was borne two-thirds by the Water Department and one-third by the Park Commission. The structure is of reinforced concrete of the Melan design and consists of three main spans of 56 feet and four approach arches, three of which are 28 feet and one of 33 feet span.

FINAL SLOW SAND FILTRATION PLANT

Radical changes were made in the design of this plant, these changes involving a type of construction which is an innovation in this character of work, no similar plant having been constructed elsewhere. After much legal discussion together with financial difficulties, the contract for this work was finally executed on December 9, 1908. Though the construction work was not entirely completed within contract time, it has been possible to operate the filter, and since January 16, 1910, filtered water has been distributed throughout the city.

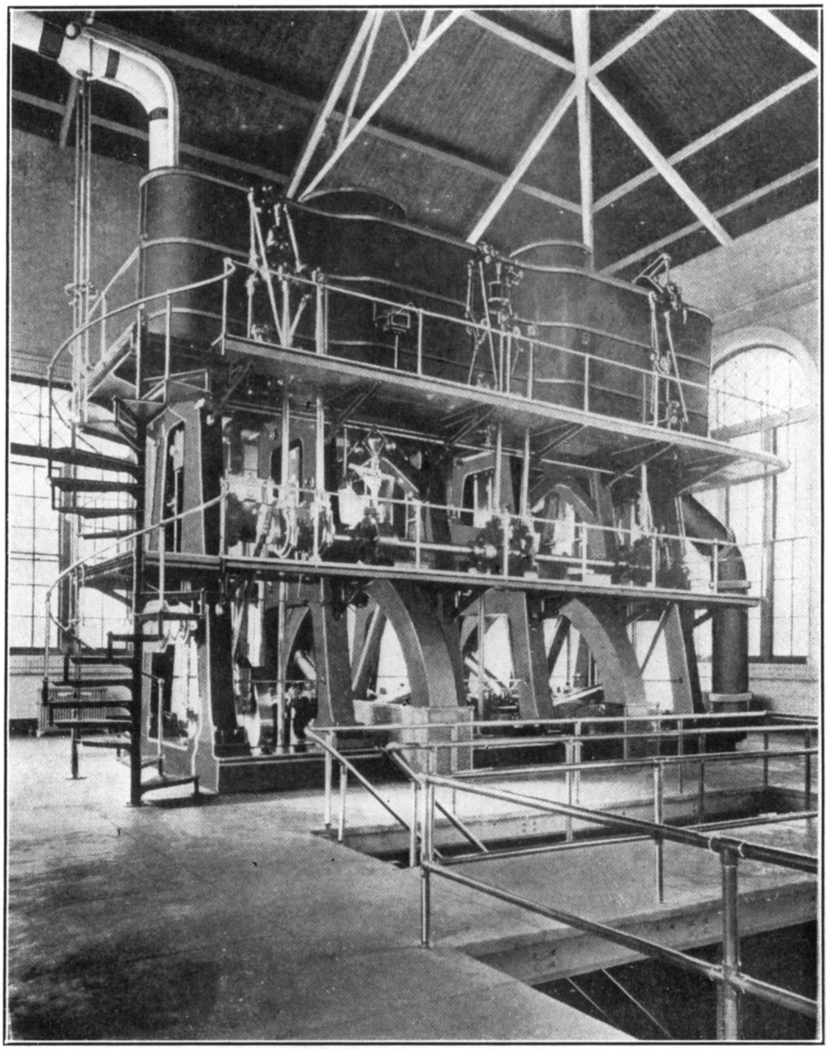


Administration Building and Slow Sand Filtration Plant

The plant consists of six covered sand filters, of one-third acre each in area, a filtered water reservoir, a sand washing machine of the Blaisdell type, in addition to a control house, Venturi meters, valves and piping, and was designed for a daily capacity of 15,000,000 gallons, although for present needs a 12,000,000 gallon capacity is ample.

The six filter units are superimposed upon a reservoir of 6,000,000 gallons capacity. At the extreme end of the works a dry gallery runs across the width of the six beds which contains the influent and effluent pipes and regulating devices, all visible and accessible.

One of the principal features in the design is that the filters and filtered water reservoir are combined in one structure two stories



12,000,000 Gallon V. T. E. Holly Pumping Engine (in Duplicate)

high. The reservoir or lower story has a groined arch roof supported on square piers, and this roof serves also as the floor of the filters, over which extends a roof of concrete slabs supported on I-beams. This form of construction effected a considerable saving in concrete and in excavation. If the two parts had been built separately a roof would have been necessary for each. There is also the obivious saving in land area. With such a grouping of the parts there is, of course, a far greater loss of head than in the case when the structures are built separately. Local conditions had a large influence in the selection of this type of structure, for the works are on high ground, and the loss of head between the filters and the reservoir is not a matter of any great consequence.

Another unusual feature is the shape of the beds, which are long and narrow; they measure 362 by 40 feet, and were built of this size in order to use a sand washing machine.

The system of underdrains also is somewhat unusual, for the filter effluent collected by a tile pipe drain passes through holes in the floor into a discharge pipe hung up close to the roof of the filtered water reservoir.

This reservoir measures 364 by 252 feet inside, and has a plain concrete floor of inverted groined arches. The piers, which are spaced on 14 feet centers, are 24 inches square and 6½ feet high from floor to the springing line of the groined arch vaulting. The minimum thickness of floor and roof is 9 inches.

The filters which form the second story of the concrete structure are separated from one another by concrete walls, which are placed over every third pier across the width of the plant. These walls are 24 inches thick and 9 feet high, and along their side are bolted cast iron brackets, which support rails for carrying the trucks of the sand washing machine. In the top of each wall a channel is cast and will serve to convey the dirty wash water from the washer to the waste pipe connected to a sewer. The underdrainage system consists of one row of Brossman tiles, laid longitudinally down the center of each filter. These tile drains are 2 feet long and have a section resembling a flat inverted V. Water may enter these through four openings, two on each side. They are bedded to the floor by a coat of grout, and are covered with a 15-inch layer of broken stone.

Under the tile pipe collectors at 14 feet intervals along the longitudinal axis of each filter compartment holes are cast in the concrete floor and extend through to the reservoir below. The purpose of

these holes is to afford an outlet for the filtered water, and at the same time serve as a means of supporting the effluent pipes, which are suspended under the roof of the filtered water reservoir, and extend the long way of each bed, running directly beneath the main tile collectors. The effluent pipes are of cast iron, increasing from 6 to 20 inches in diameter. The effluent piping suspended at 14 feet intervals for its entire length, connects with a main effluent pipe in the dry gallery at the end of the plant.

The lower courses of the filtering material are 14 inches of crushed stone and graded gravel, and on them rests a layer of sand 24 inches thick. The sand was dredged from the Delaware River and had an effective size of 0.23 mm. and a uniformity coefficient of 1.83. The head of water on the sand is $4\frac{1}{2}$ feet, and the beds are operated at a nominal rate of 6,000,000 gallons per acre daily for the present, although it is believed that a rate of 8,000,000 gallons can be used by taking precaution to sterilize the filtrate.

The roof of the filters is of concrete reinforced with triangular wire mesh. It is laid in 3 inch slabs upon 8 inch I-beams, and supported by I-beam columns, resting on the walls dividing the filter beds. The roof has a slope from the center toward either side of $\frac{1}{4}$ inch in 1 foot.

At the southwest end of the plant, across which the dry gallery extends, the roof had to be raised a few feet in order to afford clearance for the sand washing machine when it is transferred from one bed to another. A continuous bracket cast in each gallery wall carries the rails, along which a transfer carriage travels. This carriage carries a pair of rails spaced 38 feet apart, the same gauge as those of the filter beds, so that the machine may pass from the beds to the transfer carriage and then be carried by it transversely to any position in the gallery which may be desired.

At the northwest end of the pipe gallery there is a valve chamber to control the head of water on the beds. Water enters it by gravity through a 48-inch and 30-inch pipe from the sedimentation reservoir, which ends with a 30-inch hydraulic and hand operated disc valve originally intended to be operated by a float in the chamber. By a simple and occasional adjustment of the hand wheel the water is maintained at a uniform level on the filters. From the valve chamber the water enters an influent main running the length of the gallery, reducing in size at each bed from 30 to 16 inches in the total length of the gallery. This main has a 16-inch branch at each bed, and

water from it discharges into a channel along the end of each filter and flows over the inner edge, which acts as a weir, and down through the sand. The filtered water after passing through the pipes suspended from the roof of the filtered water reservoir, discharges through a Venturi meter on each bed, into the main effluent collecting pipe and thence into the filtered water reservoir.

The final or slow sand filters were placed in operation January 16, 1910.

Table showing average bacteria per cubic centimeter raw, pre-filtered settled and final effluent waters

YEAR	RAW	PRE-FILTERED	SETTLED	FINAL EFFLUENT
1910	17,517	8,261	16,177	1,012
1911	36,546	18,507	17,056	146
1912	36,948	24,855	20,257	491
1913	18,042	12,448	10,009	207
Average......	27,263	16,025	15,8 75	464

Bacteria removed by,	*per cent*
Pre-filters..	41.23
Settling basin..	00.94
Final filters..	97.08
Total..	98.30

Table showing average percent of positive presumptive tests for B. Coli-communis, in 1 cc. samples, raw, pre-filtered, settled and final effluent waters

	RAW	PRE-FILTERED	SETTLED	FINAL EFFLUENT
	per cent	*per cent*	*per cent*	*per cent*
Average......	97.9	93.4	90.9	11.2

B. Coli-communis removed by,	*per cent*
Pre-filters..	2.56
Settling basin..	2.68
Final filters..	87.68
Total..	88.52

The general bacterial removal was higher than that of the B. Coli-communis.

Table showing average turbidity, in parts per million, raw, pre-filtered, settled and final effluent waters

YEAR	RAW	PRE-FILTERED	SETTLED	FINAL EFFLUENT
1910	52.0	19.0	16.0	0.0
1911	60.0	27.0	15.0	0.0
1912	85.0	49.0	43.0	2.0
1913	72.0	53.0	37.0	0.1
Average......	67.2	37.0	27.8	0.8

Turbidity removed by,	*per cent*
Pre-filters	44.95
Settling basin	24.87
Final filters	71.23
Total	98.82

The total bacterial removal is about the same as the total removal of the turbidity.

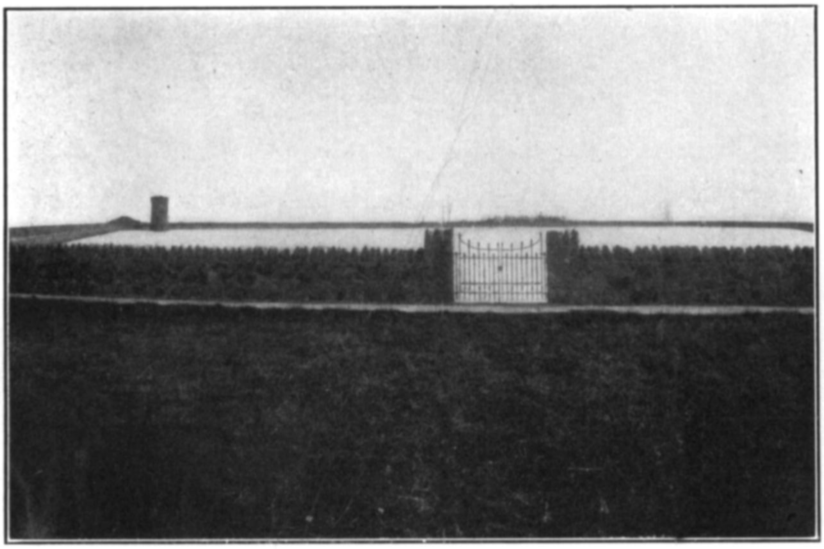
As a large portion of the turbidity is removed by the prefilters, there is little work for the settling basin to do, the size of the particles passing these filters being very small, the amount that settles is very slight. There is no mechanical action to assist in carrying down the bacteria, hence the removal by the settling basin is small.

The color of the water has been determined only during the past two years.

Table showing average color, in parts per million, raw, pre-filtered, settled and final effluent waters

YEAR	RAW	PRE-FILTERED	SETTLED	FINAL EFFLUENT
1912	25.0	23.0	24.0	11.0
1913	21.0	21.0	20.0	6.0
Average......	23.0	22.0	22.0	8.5

Color removed by,	*per cent*
Pre-filters	4.35
Settling basin	0.00
Final filters	61.37
Total	63.05



Wm. T. Porter Reservoir

Brandywine Pumping Station

As no coagulant is used, the removal of the color is not high or complete.

The final effluent during eight months of 1913 was treated with liquid chlorine.

Table showing average bacteria per cubic centimeter and per cent of positive presumptive tests for B. Coli-communis in 1 cc. samples, before and after liquid chlorine treatment

BACTERIA PER CC.		B. COLI-COMMUNIS	
Before	After	Before	After
		per cent	*per cent*
302	51	11.97	2.77

These results show that the liquid chlorine removed 83.12 per cent of the bacteria and 76.86 per cent of the B. Coli-communis.

The amount of liquid chlorine applied averaged 1.56 pounds per 1,000,000 gallons.

During January 1912, there was an epidemic of typhoid fever at Coatesville, Pennsylvania (on the watershed). No notice of this condition was sent to the water department until the epidemic was well under way, and before an emergency hypochlorite plant could be installed and placed in operation the filters had failed to remove the bacteria and several cases of fever started in Wilmington.

When the condition of the water-shed was learned an emergency hypochlorite plant was placed in operation, the hypochlorite being added to the water after it left the settling basin and before it was upon the final filters. This treatment killed the bacteria in the water and also those on the beds, and it was several months before the beds returned to normal working conditions. In the mean time a more permenant hypochlorite plant was placed in operation and the final effluent was treated.

The use of hypochlorite prevented a serious outbreak of typhoid fever in Wilmington.

After this experience, experiments were made with liquid chlorine, the results being so satisfactory that a permenant plant was installed and during 1913 it was operated eight months.

Table showing typhoid fever deaths and rate since completion and operation of final filters or total plant

YEAR	DEATHS	RATE
1910	32.0	36.0
1911	24.0	27.0
1912	24.0	26.0
1913	11.	12.0
Average	22.7	25.2
Average for two years when only pre-filters were in operation	23.0	25.5

The average results show that the typhoid fever death rate did not decrease after the final filters were placed in operation.

The results do show that during the year 1913, when the liquid chlorine plant was in operation that the typhoid fever death rate was 12 per 100,000 which is 53.9 per cent less than during the previous year.

MECHANICAL WASHING OF FILTER SAND

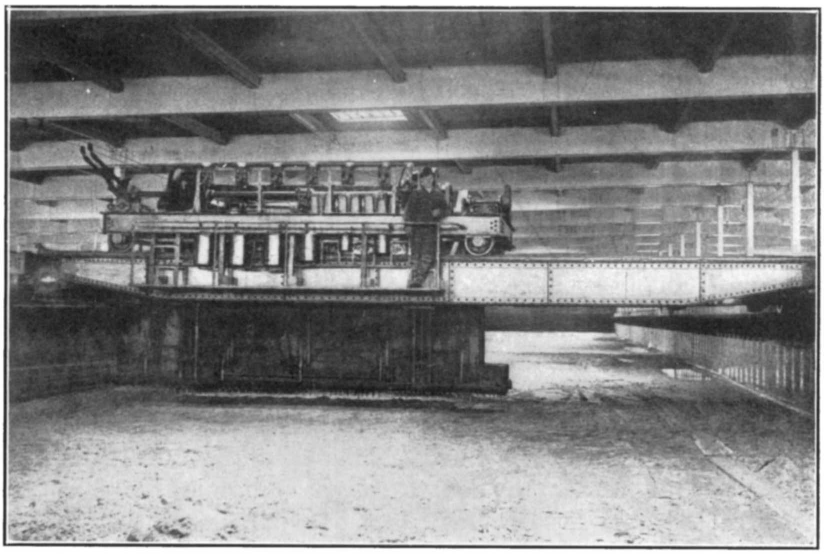
The Blaisdell mechanical washing of filter sand is a method of recent introduction, and in consequence is not as generally known or understood as those systems and methods that have been heretofore applied for filter cleaning. Briefly, the washing machine may be described as a traveling crane spanning a filter unit and supporting a watertight rectangular chamber containing the essential washing machinery, and further provided with means of lowering this chamber to the sand surface and traversing over the filter while the operation of washing the sand is proceeding. The washing chamber may be raised so as to clear the rim of the filter, and the machine removed to another unit by the transfer carriage.

As the width of each filter bed is forty feet, the span of the main traveling crane supporting the washing chambers was made thirty-eight feet on rail centers. Forty pound rails were used, supported on specially designed cast iron brackets bolted through the division wall on 2½ feet centers.

In the design of the machine the water tight washing chamber was made 20 feet long by 4 feet wide by 5 feet 6 inches deep. Approximately 2 feet above the sand level or bottom of this chamber there is a plate or diaphragm subdividing the washing chamber into two compartments: the lower known as the suction chamber, from which

the dirty wash water is withdrawn, contains five horizontal stirrer wheels supported on vertical shafts; the upper, or dry chamber contains the driving mechanism for the stirrer wheels and also the pressure and suction pumps.

As the width of the bed is 40 feet, and the area washed in the forward movement of the machine is but 20 feet, the entire washing chamber is supported upon crane beams mounted upon wheels, for the purpose of moving it laterally across the width of the bed, on rails supported on the girders of the main traveling crane. This permits of com-



FILTER SAND WASHING MACHINE

pleting the washing of the entire bed in one round trip of the machine, i.e., by moving forward over the entire length in one position a width of 20 feet is cleaned and by transferring the chamber to the opposite end of the main crane, which transfer is made without stopping washing process, the remaining area is cleaned upon the return trip, leaving the entire machine ready to be transferred to any bed without undue loss of time.

The stirrer wheels in the lower or suction chamber are supported by vertical shafts in a horizontal position 1 inch above the sand surface. Numerous teeth project from the lower face of the stirrer wheel rim

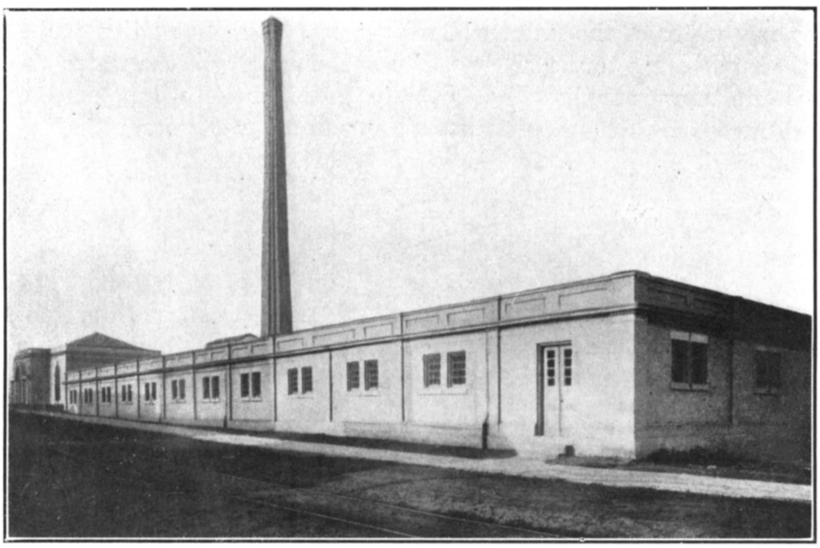
and extend into the sand below the level of the chamber to any desired depth. Each vertical shaft passes through a stuffing box in the top of the chamber to an upbearing in the frame of the machine, and is revolved by a motor actuated worm gearing at the upper end. Midway of the shaft there is a T-shaped sleeve, with stuffing boxes at the upper and lower ends, which serves as a water connection. From this sleeve downward each shaft and wheel including spokes and rim are hollow. The teeth are hollow and perforated for the purpose of creating a water jet action from the supply delivered by pressure pump. Water supply for the pressure pump is taken from the raw water of the filter, while at the same time a suction pump connected to the top chamber withdraws not only all the water the pressure pump supplies through the perforated teeth, but also an additional quantity made up from the filtered water stored in the filter sand. In operation, the teeth scour the sand; the wash, or pressure water, by the jet action prevailing, drives the dirt up into the suction chamber; the clear water stored in the filter bed is drawn into the washing zone by the excess suction over pressure supply, and the wash water is withdrawn and pumped from the chamber before the machine passes a given point. The chamber is sealed to the sand surface by wide hinged shoes extending in advance and to the rear of the front and back plates, while the side plates form a cutting edge extending down into the filter sand.

The maximum speed of operation is governed by the rapidity with which the pressure pump water may be displaced by the filter bed supply, and as a result the speed of advance varies with the length of teeth used, or in other words, the depth of the washing.

Due to the fact that there is less dirt at the lower depths of the filter than near the surface, it is necessary when washing to a considerable depth such as 24 inches, that teeth of proportionate length be fixed in the stirrer wheel, and the wash water is therefore introduced not only at the lowest point, but at several points above. This pressure water quickly rises through the disturbed sand zone and is displaced by the inrush of the clear water, the upward current of which occurs well toward the center of disturbance created by the teeth and covered by suction chamber. The sand grains are dislodged and forced apart by the passage of the teeth, and as they return to the cavity in the wake of the teeth the strong upward current of wash water creates a temporary suspension and churning action within the area of the suction chamber. During this time the dirt

and light particles are swept to the surface and withdrawn with the wash water. The subsidence of the suspended sand takes place following the passage of this violent upcast and occurs during the more gentle upward passage of the clear water, so that when the sand comes to rest it is uniformly water packed and free from all air.

As each stirrer wheel revolves five times per minute and mounts thirty-two teeth, it follows that all sand grains are disturbed several times, both by direct contact with the teeth as well as by the working of adjacent sand and the horizontal water jets, from the teeth.



Preliminary Filter Building

The washwater may be controlled to enable hydraulic sizing if so desired, working all very fine sand to the surface, and if sand too fine for effective size is present, it is possible to remove it from the filter by increasing the duty of the pressure and suction pumps to secure the desired upward velocity to hold the sand in suspension. At all times the excess suction demand is satisfied by the supply of clear water stored in the filter sand.

The dirty wash water from the machine is discharged to a gutter formed in the concrete party wall between the filter sand units, from which there are sewer connections at either end. This gutter is about 18 inches deep, 10 inches wide at the top and 6 inches at the

bottom, with a slight grade either way from the center of the beds to the drains at the ends, but the slope is not enough to allow any sand raised to proceed to the sewer system. Sand that collects in the gutter is removed with a spade and returned to the filter or taken away as desired.

The party walls serve to support the brackets for the rails on which the washing machine travels, and also the steel columns supporting the roof over the plant. The wash water gutter is placed off the center line of the wall to enable the discharge spout from the machine to pass the columns.

All of the several operations of the mechanical features of the machine are actuated by independent motors controlled from the platform by one operator. There are six motors mounted on the machine with variable speed controllers for operating as follows:

	CAPACITY H.P.	MINIMUM H.P.	MAXIMUM H.P.
Main traveling crane	25.0	5.0	15.0
Washing chamber transfer	7.5	1.5	2.5
Washing chamber hoist	7.5	5.5	5.5
Stirrer Wheel drive	20.0	5.0	20.0
Pressure pump drive	25.0	12.0	15.0
Suction pump drive	10.0	3.0	5.0
	90.0	32.0	63.0

Actual experience has demonstrated that but 54 horse power is required for the worst conditions of operation, and 25 horse power with short teeth and normal conditions. The quantity of current consumed in washing each bed of one-third of an acre in area has ranged from 80 to 175 kilowatt hours, and averages throughout the year approximately 120 kilowatt hours. The current consumed and power required is least when the shortest teeth are being used and reaches a maximum with the longest teeth during the winter months, when the oil gear boxes tend to congeal and the operation of the machine is hampered by ice on the filter beds.

With a five unit machine cleaning a strip 20 feet wide, one operator washing one-third of an acre in four hours, including transfer, and the bed is usually back in service within five hours from time of closing valves for washing process. This question of time element naturally effects the reserve area of plant that must otherwise be constructed

in order to maintain normal rates of filtration throughout. The experience of the Department has been that the time out of service by this method per acre area ranges from 7.5 per cent to 10 per cent, while with the old method of hand scraping, ejecting, and restoring, from 15 per cent to 25 per cent of time is lost. It is apparent therefore, that the construction cost, either for reserve area or plant capacity for low rates of filtration, is materially reduced by this improved mechanical method of filter cleaning.

The method also had a material effect upon the cost of operating sand filters, effecting a reduction in our plant of approximately 50 per cent over the cost of operation of plants of the same capacity elsewhere, notably Philadelphia.

It was confidently expected when the plant was built that the operating cost would not be greater than $1 per 1,000,000 gallons, exclusive of laboratory charges. We have not, however, been able to reach this low figure, the cost in the year 1910–11 being $1.08. As the operations of the plant require intelligent superintendence at all times, and as skilled mechanics must be employed continuously for operating the washing machine, notwithstanding that it is idle approximately 75 per cent of the available working time, it is evident that with a larger daily delivery in million gallons, the above unit cost which involves a considerable overhead or fixed expense, could be materially decreased.

When the turbidity of the settled or applied water is above 50 parts per million, it is impossible to get a filtrate that is entirely satisfactory.

At one time, during cold weather, it was necessary to use dynamite to dislodge the ice from the filters.

The most serious trouble is from "air bound" beds, during the winter months, when the water is saturated with oxygen.

These slow sand filters produce results equal to other plants of the same type while the troubles are no greater.

The installation of the liquid chlorine plant has proved to be a very valuable addition.